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RESULTS OF INITIAL EXPERIMENTS TO CONFIRM CALCULATIONS OF SLACK--ETC(U)

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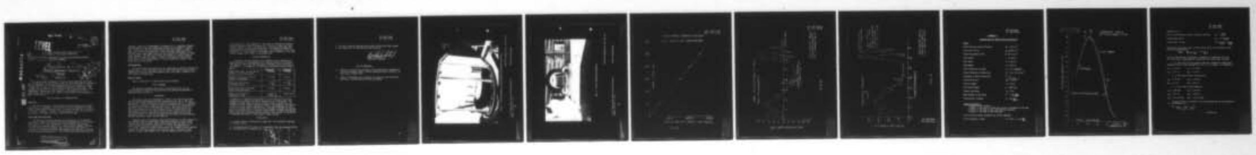

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USL Problem
No. 1-650-01-00

U. S. Navy Underwater Sound Laboratory
Fort Trumbull, New London, Connecticut

RESULTS OF INITIAL EXPERIMENTS TO CONFIRM CALCULATIONS OF SLACK TOWLINE PHENOMENA

by

Fred J. Contrata, Jr

USL-TM-

USL Technical Memorandum No. 933-121-64

2 June 1964

13p.

INTRODUCTION

USL Report #558 (reference (a)) analytically describes the slack towline phenomena that occur when a body is towed under certain conditions. The test described in this memorandum was made in an attempt to induce a slack towline condition and to measure concurrently the force at the towstaff and the vertical accelerations of the fish and the ship. This experimental information, when compared to the predictions of USL Report #558, should serve as a check on the validity of the assumptions made in the report.

TEST EQUIPMENT AND INSTRUMENTATION

Towed Body

The towed body used in these "variable density tests" was an SQA-10 fish without a transducer. The body was fitted with removable ballast, which allowed varying the fish weight in water from 3260 lbs. to 5500 lbs. in 230-lb. increments. Figure 1 is a photograph of the towed body with and without its window, with the lightest ballast used.

Force Gage Bearing Blocks

The bearing blocks were modified by the addition of an extended force ring. Figure 2 shows the load-carrying member prior to the strain gage installation. The configureation was chosen for two reasons: (1) there is no practical way to put a simple tension member in series with the towline at the towstaff; and (2) the force ring offers an opportunity to measure the forces perpendicular and parallel to the base of the bearing block separately. The stress-strain relationship for an

octagonal force ring is discussed in reference (b). A modified octagonal ring was used for the tests undertaken aboard the USS SPERRY in August 1963. Only one of the two bearing blocks was strain-gaged in order to read only the force perpendicular to the towed body longitudinal axis. The four strain gages were potted with PRC compound and checked for leaks under pressure. The bearing block was calibrated on a tension machine at Mitchell College, New London. Figure 3, the resulting calibration curve, shows the block sensitivity. A load of 4900 lbs. causes a 1000 micro-inch per inch strain.

Accelerometers

One accelerometer was mounted in the towed body to measure accelerations perpendicular to the longitudinal axis of the towed body; a second accelerometer was mounted in the after-steering room of the ship to measure fantail vertical accelerations.

Data Recording

Data was recorded on a Sanborn 850 analog recorder.

TEST PROCEDURE

The fish was streamed with 75 feet of cable payed out, and the fish acceleration trace was monitored while the ship was maneuvered to maximize fish acceleration.

DISCUSSION

The towing tests were performed in a state 3 sea, during which the fantail experienced maximum vertical accelerations of .35 G. The fish was unable to attain a free-fall acceleration greater than .24 G. Whenever the fish was permitted a negative vertical acceleration of this magnitude or greater, the towline invariably went slack. The slack towline condition is clearly shown in the recording of the fish acceleration and the towstaff tension. The slack towline condition could also be seen by watching the towline between the drum and the sheave go slack and sag from 1/2 foot to 2 feet at the same time the tension and acceleration records indicated a slack towline condition.

Figures 4 and 5 are records, taken simultaneously, of fish acceleration and towstaff tension, respectively, during one period in which a slack towline condition occurred. Both curves clearly show the onset of the slack towline condition occurring at $t = 3.5$ sec. and persisting to $t = 5.5$ sec. During the slack towline period the towstaff tension remained constant at 1250 lbs., instead of dropping to zero. 700 lbs. of this tension is due to measurement error, and the remaining 550 lbs cannot

be accounted for. The recapture of the fish was attended by towstaff tensions between 22 and 30 thousand lbs. Typically, there were three distinct peaks of tension and acceleration, of decreasing magnitude, associated with the recapture of the fish. The frequency of this free vibration is 1.5 cps, which is the damped natural frequency of the fish-towline system with 75 feet of cable payed out.

TYPICAL COMPUTATION

Appendix A shows the results of a computation for conditions as nearly identical to the measured slack towline condition as possible. The times are taken from the time axes in Figures 4 and 5 and Figure 1 of Appendix A. A comparison of computed and measured values are shown below.

	Measured	Computed
Time (after start of ship motion period) towline went slack	3.8 sec.	3.7 sec.
Length of time slack towline condition persisted	1.7 sec.	2.2 sec.
Fish sink acceleration (G factor x32.2)	$7.75\ \frac{ft^2}{sec.}$	$8.8\ \frac{ft^2}{sec}$
Time (after start of period) slack condition ended	5.5 sec.	5.9 sec.
Peak cable tension at recapture of fish	22,000 to 30,000 lbs.	79,000 lbs.

A comparison of computed and measured G factors shows that the value computed by the method outlined in reference (a) is 14% larger. The agreement between these two values is good enough to justify the continued use of the present computation method. The measured and computed tensions, however, differ considerably. This may be because the computation was made under a zero ship speed assumption whereas the measurements were carried out at a seven-knot ship speed. Forward speed should cause a decrease in maximum tension; however, the data are not sufficient to determine the effect of ship speed on peak tensions.

CONCLUSIONS

1. Downward fantail accelerations larger than .24G invariably resulted in a slack towline.

2. The measured fish "G" factor is in agreement with the value calculated by the method used in reference (a).

3. The peak tensions measured were between 22,000 and 30,000 pounds at the termination of the slack towline condition.

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FRED J. CONTRATA, JR.
Mechanical Engineer

LIST OF REFERENCES

(a) "Effects of Certain Ship Motions on Cable Tensions in Systems for Handling Submerged Bodies," USN/USL Technical Report #559 by F. B. Rakoff dtd 7 August 1962

(b) "Physical Measurement and Analysis," by Nathan H. Cook and Ernest Rabinowicz, Addison-Wesley Publishing Company

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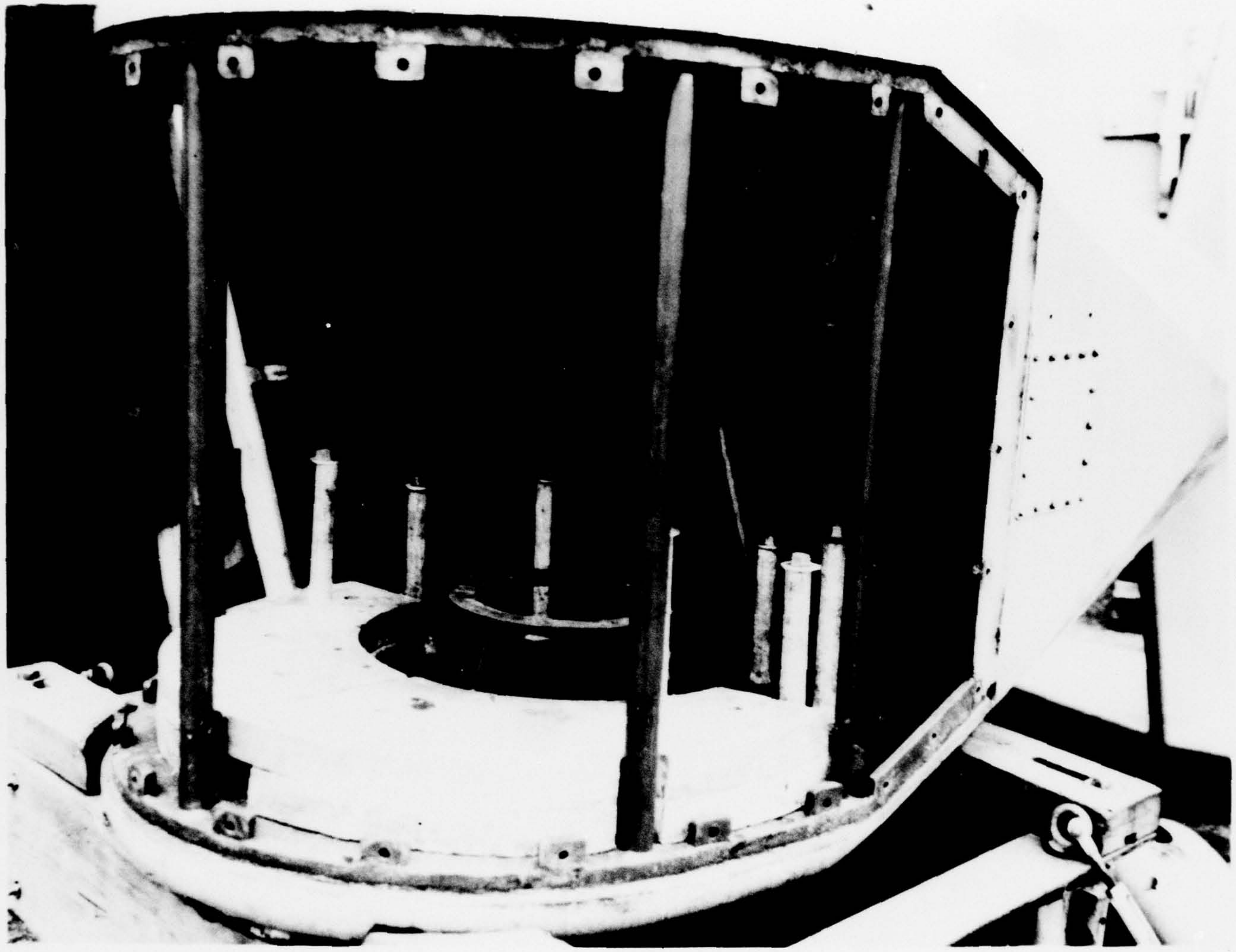

Fig. 1 - Variable Density Towed Body with Window Removed

USL Tech Memo No. 933-121-64

U. S. Navy Underwater Sound Laboratory
NP24 - 24178 - 5 - 64

Official Photograph

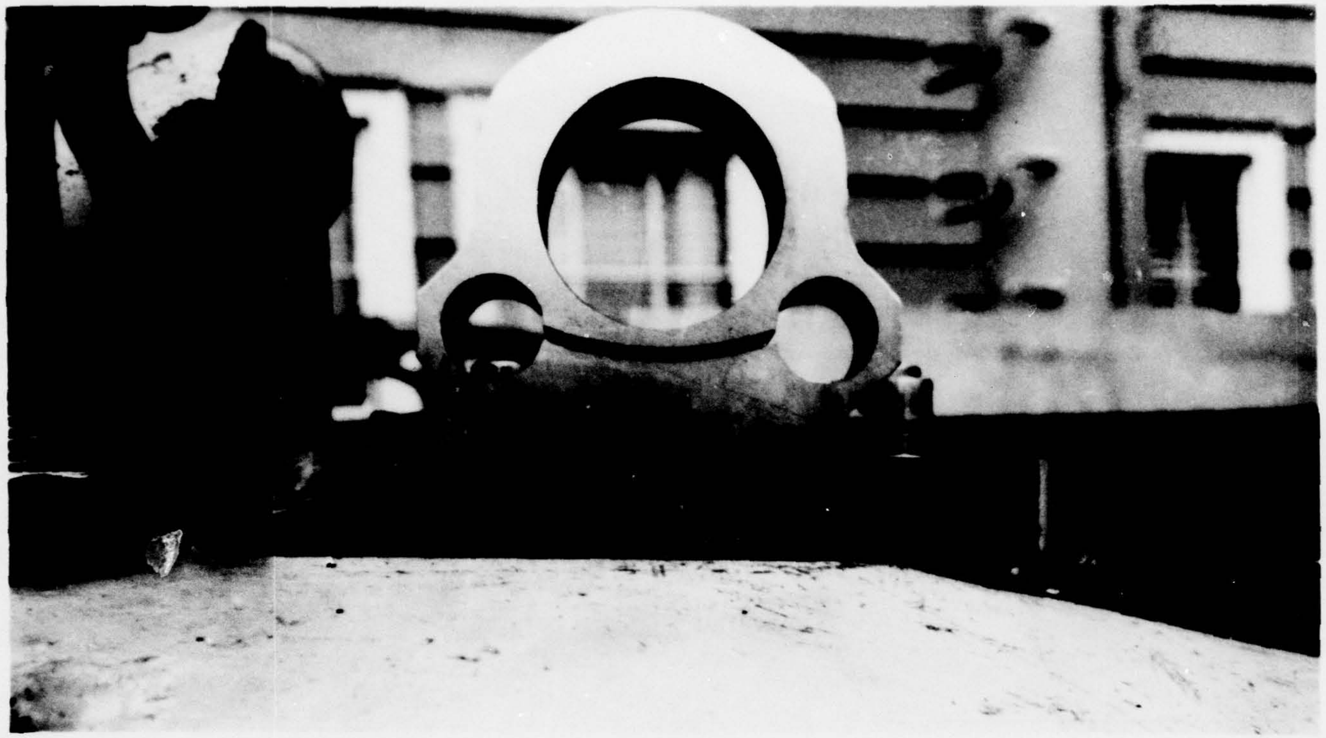

Fig. 2 - Force Gage Bearing Block

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U. S. Navy Underwater Sound Laboratory
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Official Photograph

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No. 933-121-64

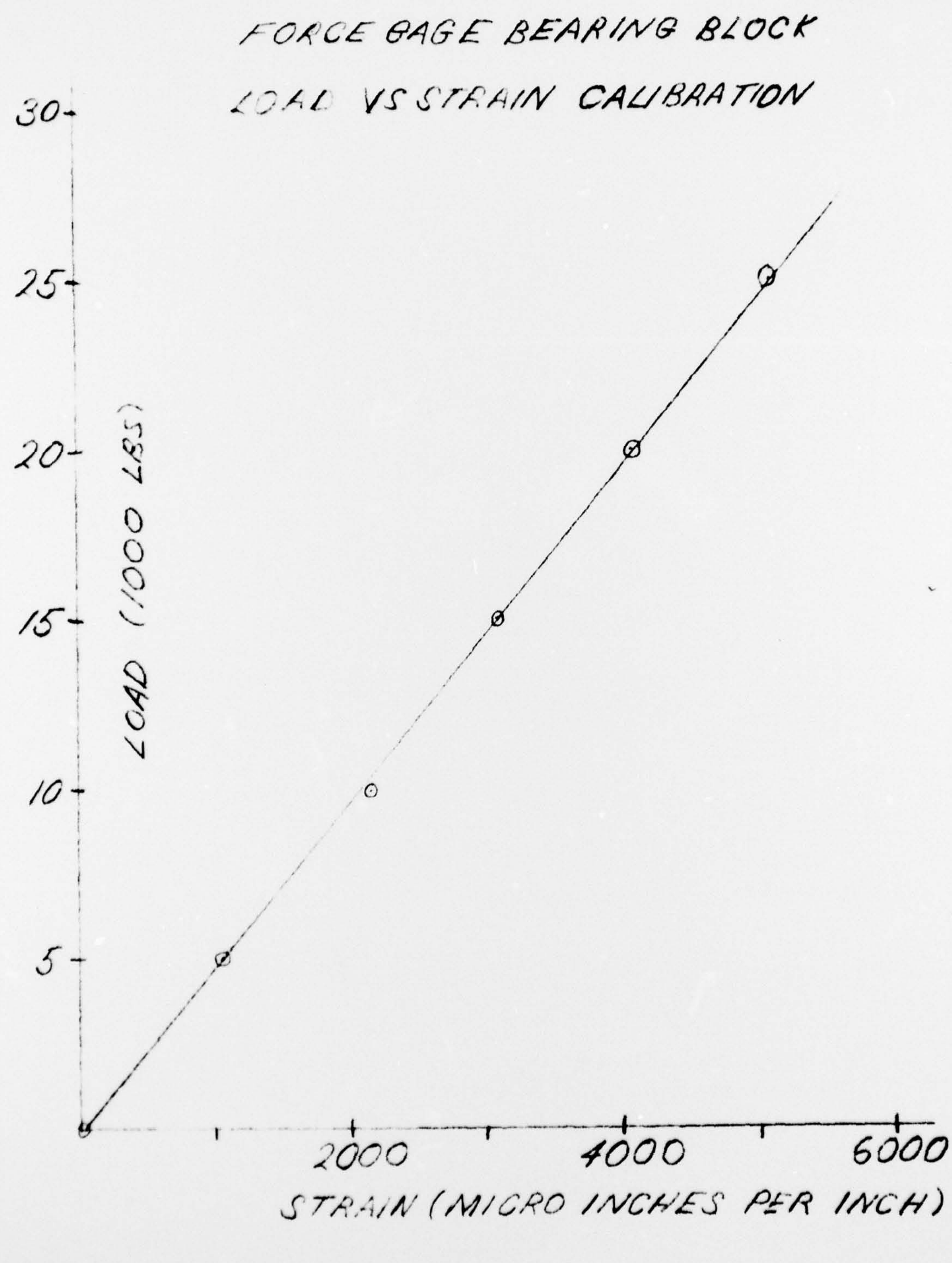


FIG 3

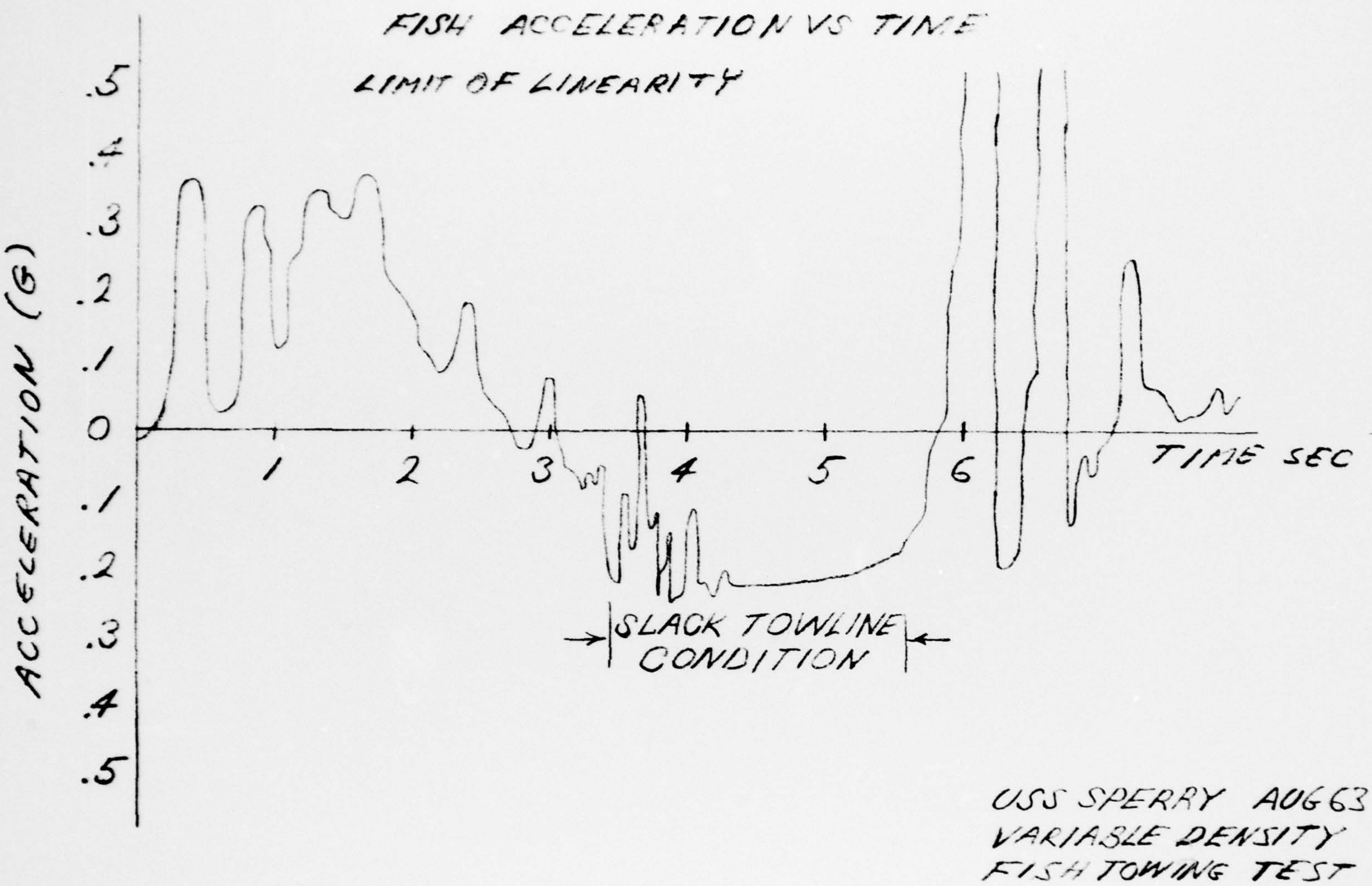
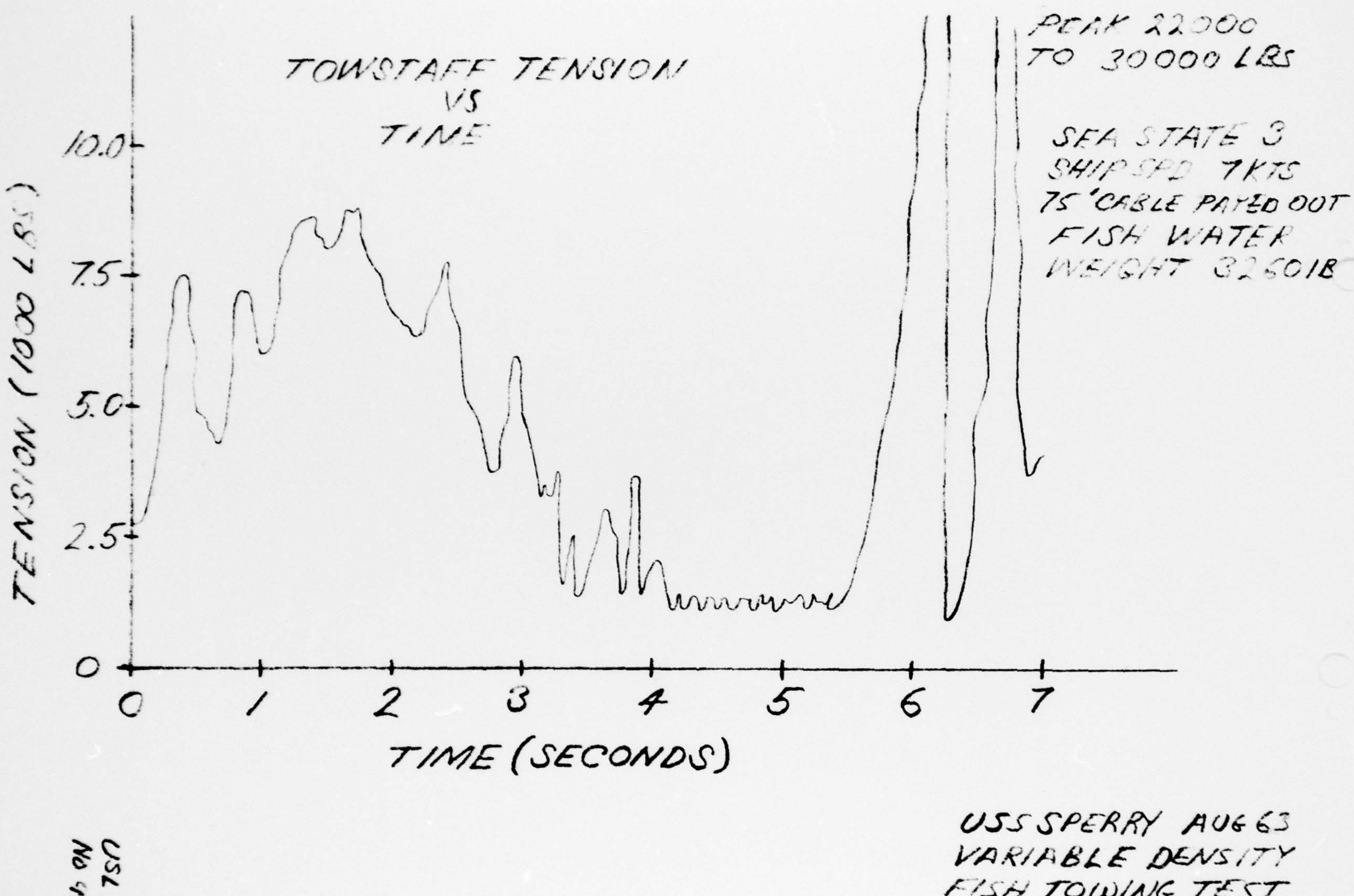

FISH ACCELERATION VS TIME
LIMIT OF LINEARITY
.5
.4
.3
.2
.1
0
.1
.2
.3
.4
.5
ACCELERATION (G)
1
2
3
4
5
6
TIME SEC
SLACK TOWLINE CONDITION
USS SPERRY AUG 63
VARIABLE DENSITY
FISH TOWING TEST

FIG 4



USL TECH MEMO
NO 433-121-64

FIG 5

APPENDIX A

Computations for Slack Towline Conditions

Given:

Cross Sectional Area of Towline	$A_c = 1.42$ in.^{2}
Plan Area of Fish	$A_p = 30.66$ ft.^{2}
Volume Enclosed by Fish	$B = 80.13$ ft.^{3}
Fish Length	$l = 11.83$ ft.
Fish Width	$b = 3.30$ ft.
Fish Height	$h = 3.92$ ft.
Fish Coefficient of drag	$C_d = 0.3$ (Assumed)
Towline Modulus of Elasticity	$E_c = 10 \times 10^6$ lb/in^2
Frequency of Ship Pitch Motion	$f = \frac{1}{5.5}$ cps
Fish Bulk Factor	$lbh = 153$ ft.^{3}
Towline Length	$l_c = 75$ ft.
Fish Water Weight	$W = 3260$ lbs.
Fantail Amplitude	$X_o = 8$ ft.
Mass Density of Sea Water	$\rho = 1.99 \frac{\text{slug}}{\text{ft}^3}$
Gravitational Constant	$g = 32.2 \frac{\text{ft.}}{\text{sec.}^2}$

Subscript Notation:

- s refers to ship towpoint
- z refers to the point at which the towline is attached to the fish
- 2 refers to the time of zero fish vertical velocity
- 3 refers to the time of fish recapture

The following related constants can now be computed:

Pitch frequency of ship $\quad K = 2\pi f = 1.141 \frac{\text{rad}}{\text{sec}}$

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No. 935-121-64

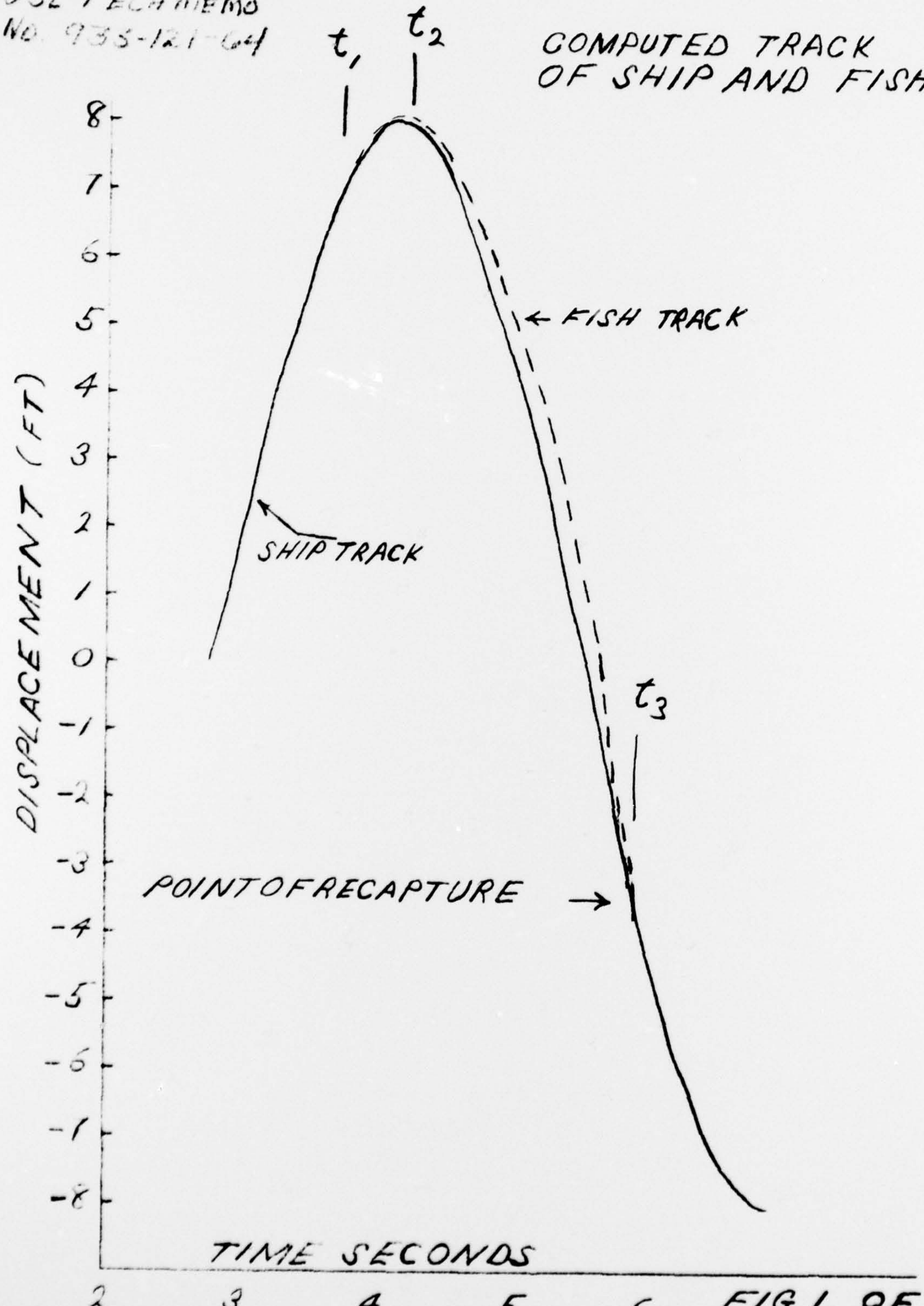

FIG 1 OF
APPENDIX A

Appendix A cont.

Ratio of fish vertical drag to vertical velocity $K_2 = \frac{C_d A_p}{2}$

Virtual Mass factor $K_5 = 1.7$ assumed

Virtual Mass of Fish $M = \frac{W K_5 (Pg)}{g} \quad \frac{\text{slugs}}{\text{ft}^3}$

By equating fish drag force to fish inertia force, the sink rate of the fish can be determined:

$$A_{z_{MAX}} = \frac{Wg}{W \quad 57 \ (1bh)} = 8.8 \ \frac{\text{ft.}}{\text{sec.}^2}$$

Following the method illustrated in Appendix A of reference (a), the following times, displacements, velocities, and tension are obtained:

1. At the time the ship towpoint vertical acceleration equals the maximum free-fall fish acceleration (Point (1) on Figure 1 of Appendix A):

$t_{1s} = 3.71$ sec $\quad t_{1z} = 3.71$ sec.

$x_{1s} = 7.12$ ft. $\quad x_{1z} = 7.12$ ft.

2. At the time of zero fish velocity:

$t_{2s} = 4.18$ sec. $\quad t_{2z} = 4.18$ sec.

$x_{2s} = 8.0$ ft. $\quad x_{2z} = 8.06$ ft.

3. At the time of fish recapture:

$t_{3s} = 5.90$ sec. $\quad t_{3z} = 5.90$ sec.

$x_{3s} = 3.53$ ft. $\quad x_{3z} = -3.53$ ft.

$v_{3s} = -8.15$ ft/sec $\quad v_{3z} = -12.5$ ft/sec.

Towline tension at recapture can now be determined by using equation 11A of reference (b):

$$T^2 = \frac{MA_c E_c \quad (V_{3z}^{\ 2} - V_{3_z}^{\ 2})}{1_c};$$

$T = 79{,}000$ lbs.

Distribution List

BUSHIPS (Code 688)
BUSHIPS (Code 689A) (3)
BUSHIPS (Code 372)
BUSHIPS (Code 373)
BUSHIPS (Code 632)
David Taylor Model Basin (Code 547)
David Taylor Model Basin (Code 548)
Applied Science Lab (Code 9300)
Telephonics Corp. (NObsr 77626)
McKiernan-Terry Corp. (NObsr 81240)
DRL (H. Hillery)(NObsr 76267)

Internal

Code 100
101
900
900A
900B
900C
930
932
933
933.2
933.3
933.4
935.6
F. Contrata
G. Christensen
R. Welsh
902
904.2 (5)
930S (3)